DPP19-2019-000834

Abstract for an Invited Paper
for the DPP19 Meeting of
the American Physical Society

Interactions between relativistic non-linear plasma waves driven by laser pulses at highest intensities.[1]

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Thanks to recent advances in powerful ultrashort laser systems we can now drive relativistic non-linear plasma waves and use them to capture and accelerate electrons to ultra-relativistic energies. The field of laser-wakefield acceleration is showing tremendous progress with a lot of research around the world focused on developing new ways to trap electrons in plasma waves to optimize the quality of the accelerated beams. The key to success is a precise control over the phase at which the trapping occurs and, at the same time, minimization of its duration. We have recently developed [1] a novel trapping method which relies on the use of two laser pulses each driving its own non-linear wake. The pulses and their wakes intersect and interact, resulting in controlled trapping of free plasma electrons into both wakes. The delay between the pulses allows to precisely control the trapping phase; the trapping also occurs in the limited overlap region, which minimizes energy spread of the generated electron beams. Due to periodicity of wake-wake interference process, periodic trapping can be achieved, and an ultrashort bunch train can be generated, which can greatly reduce deleterious effects of beam loading and space charge. This novel approach to controlled trapping can be also used to study properties of the participating non-linear plasma wakes since the trapped and accelerated electrons carry information on electron momentum distribution in the area of the wake overlap. [1] G. Golovin, W. Yan, J. Luo, C. Fruhling, D. Haden, B. Zhao, C. Liu, M. Chen, S. Chen, P. Zhang, S. Banerjee, and D. Umstadter, Phys. Rev. Lett. 121, 104801 (2018).

[1]This material is based upon work supported by the National Science Foundation under Grant No. PHY-1535700 (ultra-low emittance electron beams) and the US Department of Energy, High-Energy Physics (HEP), under Award DE-SC0019421 (Controlled Injection of electrons for the Improved Performance of Laser-Wakefield Acceleration). This support does not constitute an express or implied endorsement on the part of the Government.